A Deterministic Source of Cold Atoms

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In a far-off-resonant optical dipole trap full control of all internal and external atomic degrees of freedom can be obtained [1]. We have loaded such a trap with an *exactly* known number of Cesium atoms from a magneto-optical trap (MOT) with 100% loading efficiency. In this sense our method allows to prepare a small quantum systems with a deterministic number of atoms for further applications, for instance in cavity QED. Measured long spin relaxation time of about 4.2 s makes this system available for coherent quantum control.

In our experiment Cesium atoms are initially prepared in a MOT at kinetic energies on the order of the Doppler temperature. The atom number fluctuates due to random capture from ambient Cesium vapor and loss from the trap with an average number of 1-10 atoms at a time scale of 10 s or more. From the resonance fluorescence rate the exact number is unambiguously determined within 10 ms [2].

Once a desired number is obtained in the MOT the sample is completely transferred into the dipole trap derived from a 2.5 W Nd:YAG-laser, where it is optically pumped into one of the hyperfine ground states. The transfer efficiency into the dipole trap is $100 \pm 3\%$ which we attribute to the strong localization caused by the steep magnetic field gradient, and to transient laser cooling into the dipole trap during loading. We can also store atoms in a pure magnetic trap generating by the MOT quadrupole field with 375 G/cm gradient. In the magnetic trap only atoms with low field seeking orientation are stored and hence the efficiency is about 36%. The storage time in both cases is 51 s indicating its only limitation by collisions with residual gas atoms (see Fig. 1).

Individual quantum systems are ideally suited for the application of coherently controlled quantum processes, requiring long coherence times, however. Thus we have measured the spin relaxation time by optically preparing the atoms in one of the $F = 3, 4$ hyperfine ground states. The measured relaxation rate of about $(4.2\ \mathrm{s})^{-1}$ (see Fig. 2) is much shorter than the expected $190\ \mathrm{s}^{-1}$ scattering rate of the dipole trapping laser radiation due to suppression of spontaneous Raman scattering [3].

At the present time we need 3 atoms to securely detect the hyperfine state in a single shot. An improved setup with higher detection efficiency should make single atoms a competitor for analogous ion trap experiments and with specific advantages due to the absence of charge.

[1] M. Morinaga *et al.*, Phys. Rev. Lett.**83**, 4037 (1999)
[2] V. Gomer *et al.*, Phys. Rev.**A58**, R1657 (1998); V. Gomer *et al.*, Appl. Phys.**B67**, 689 (1998)
[3] R.A. Cline *et al.*, Optics Lett.**19**, 207 (1994)

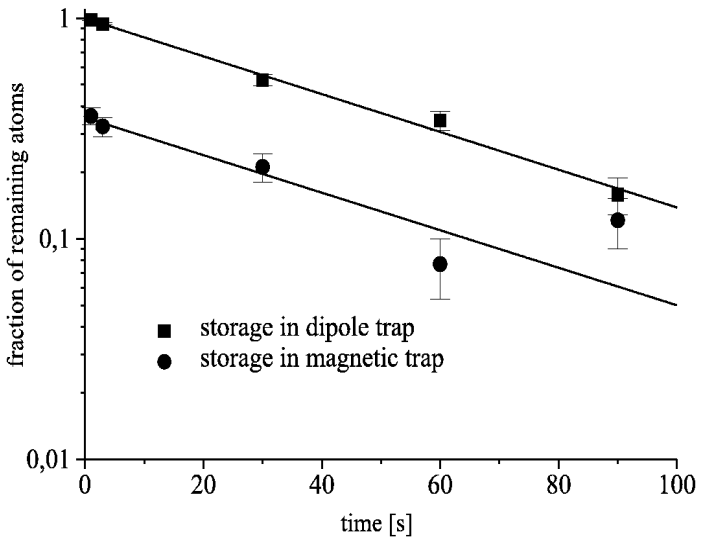

Figure 1: Measurement of the dipole trap storage time.

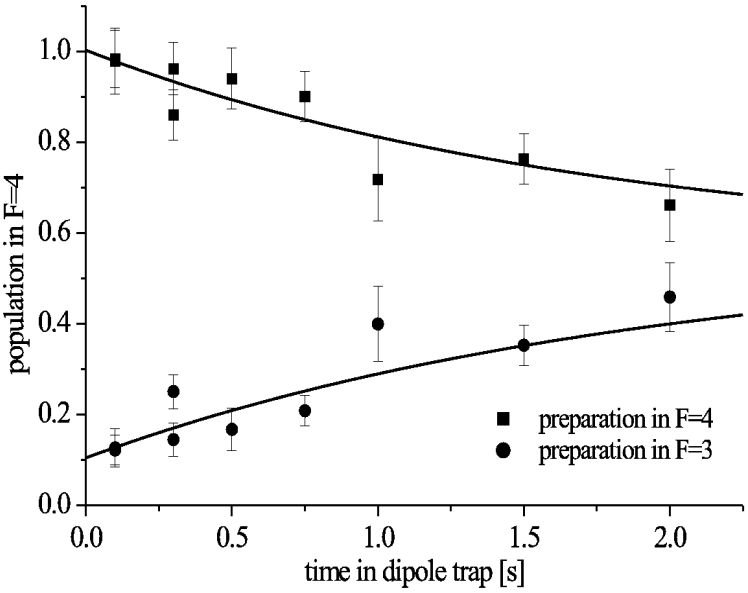

Figure 2: Measurement of the relaxation of an initial spin preparation.